INVESTIGATION OF AN ELECTROCHEMICAL MONITOR FOR TRACKING BIOFILM DEVELOPMENT AT THE BONNETT GEOTHERMAL PLANT, COVE FORT, UTAH

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Abstract

The investigation of an electrochemical probe for the real-time monitoring of biofilm development in a geothermal plant cooling system is reported. For the study, a BIoGEORGE™ Biofilm Activity Monitoring System was installed in a cooling water circulation line at the Bonnett Geothermal Plant near Cove Fort, Utah. Data collected from the instrument from December 2000 to March 2002 has been compared to operational perturbations. Instrumental readings appear to track with changes in the operational and biological activities in the plant. While the instrument is continuing to be evaluated, these initial results indicate that the instrument does show promise as an indicator of biofilm in these systems and the readings could be useful in optimizing chemical treatments used at the facility.

Introduction

Geothermal plant cooling systems present complex environments for microbiological growth. The cooling water systems use steam condensate as the primary source for make-up water. Impurities in the steam, such as hydrogen sulfide, ammonia, or carbon dioxide, may support unique microbial communities or produce adverse chemical reactions within the system components. While most of these gases are removed, some are partitioned into solution in the condensate as they accumulate in the condenser. Gases such as hydrogen sulfide may require abatement in order to protect components or meet regulatory requirements. Iron chelate is typically added to cooling water systems to treat hydrogen sulfide. The chelating compound is an organic acid, which may serve as a nutrient source for bacteria. Similarly, chemicals applied to inhibit corrosion or scaling may also provide nutrients. Some steam sources entrain droplets, which may be carried through the turbines and into the condenser and the resulting condensate. The minerals or metals, found in these entrained drops, may also influence microbial activity and/or corrosion processes. In addition, the environment in these systems cycles from reducing to highly oxygenated as the cooling water travels through the condenser and into the cooling towers. This switch from anaerobic to aerobic conditions can also influence the evolution of microbiological growth. Changes in environmental conditions can also create imbalances in the various systems that may trigger growth.

The high densities of microorganisms found in these systems can impact their operational efficiency by adhering to surfaces and participating in the development of biofilms. The formation of biofilms can adversely impact plant performance directly by impeding the heat transfer in the condenser system, or indirectly by altering the interfacial chemistry of metallic substrates influencing corrosion. In addition, microbiological growth may reduce the effectiveness of corrosion inhibitors, protective coatings, or other chemical treatments used in the plants. The economic impact of this activity may be as high as $500,000 per year for a 100 MWe plant.

In spite of the high costs associated with biofouling, most plants do not have monitoring programs in place to track biological activity, and in particular, to assess initiation of biofilm development (Pryfogle, 2000). Generally, this activity is inferred from measurements used to detect chemical fouling and corrosion including: deployed coupons, conductivity, or electrical resistivity analyses; or the evidence of pressure drops and heat transfer degradation. Fouling or heat transfer probes can provide an indication of the amount of material deposited on their surface, but do not identify the composition of the deposited material. Similarly, the methods used for assessing corrosion are also not specific to biological activity. Typically the presence of a biofilm is inferred from counts of biological organisms cultured from water samples. While microbial culturing techniques can provide data on the densities of organisms found in process fluids, they require at least 24 hours for incubation, and the data obtained does not necessarily correlate with surface fouling. With no definitive means of determining the on-set of film formation, most facilities either apply treatments on a preset schedule, or on an as-needed basis corresponding to the visual evidence of growth, creating the potential that an improper dosage of biocide is added to the stream.

This work is investigating application of a commercially-available, electrochemical monitor (Licina and Nekoksa, 1993, Licina, 2001) that has been specifically tailored for the detection of biofilm formation. The BIoGEORGE ™ Biofilm Activity Monitoring System has been installed in a cooling water circulation line at the Bonnett Geothermal Plant located near Cove Fort, Utah. Bonnett Geothermal is a flash-steam plant operated by the Utah Municipal Power Agency that produces ~7 MW of electricity. The plant represents a typical operation in that growth problems do occur at the plant, treatments are applied on a pre-defined schedule, and traditional methods (pressure drop and biological cell counts) are used to identify and assess problems.

Biofilm Monitor Operation and Deployment

Figure 1. BIoGEORGE ™ Monitor

The BIoGEORGE ™ Biofilm Activity Monitoring System is pictured in Figure 1. The system, procured from Structural Integrity Associates (San Jose, California), consists of a stack of stainless steel discs comprising two identical electrodes. The electrodes are electrically isolated from each other and from the stainless steel plug that serves as the body of the probe. (An epoxy resin fill between the electrodes produces a circular cylinder of metal discs and insulating resin.) One electrode (set of discs) is polarized relative to the other for a short period of time each day to a preset DC potential.

The polarization cycle is believed to produce an environment that encourages biological growth on the discs (Nekoksa and Gutherman, 1991); and therefore, growth may occur on the instrument before fouling plant components. Biofilm formation is detected as an increase in the applied current required for achieving the preset potential. The instrument also monitors the current generated between the two electrodes when no external potential is applied. This current can also provide an indication of biofilm formation.

The electronics for the control, data acquisition and data analyses are housed in the box pictured at the left of the probe. The system collects and stores potential and current readings as a function of time from the probe and updates the user display every few seconds. Every ten minutes, these data points are written into an on-board database. The system software then calculates the baseline values for the applied and generated currents. Individual measurements are compared with these baseline values to determine the extent of biofilm development on the probe. The controller also contains three light emitting diodes that provide an easy-to-interpret, visual status of the probe's condition. A green light indicates that no film has been detected, a yellow light indicates that the probe is evaluating or establishing the baseline, and a red light indicates that a biofilm has been detected. The logic for these alarms is guided by settings supplied by the users. Data can also be downloaded to a personal computer through an RS-232 port and imported into a spreadsheet for trend analyses, or for comparison with other plant parameters. The unit is compact, operates on 110 VAC, and contains built-in battery backup.

The stainless steel probe was installed into a two-inch pipe that by-passes a valve in the cooling water line upstream of the condenser, as shown in Figure 2. The flow in the pipe was set to achieve a fluid velocity approaching that in the condenser tubes. The probe was positioned at a 45-degree angle in the pipe to minimize the build-up of debris.

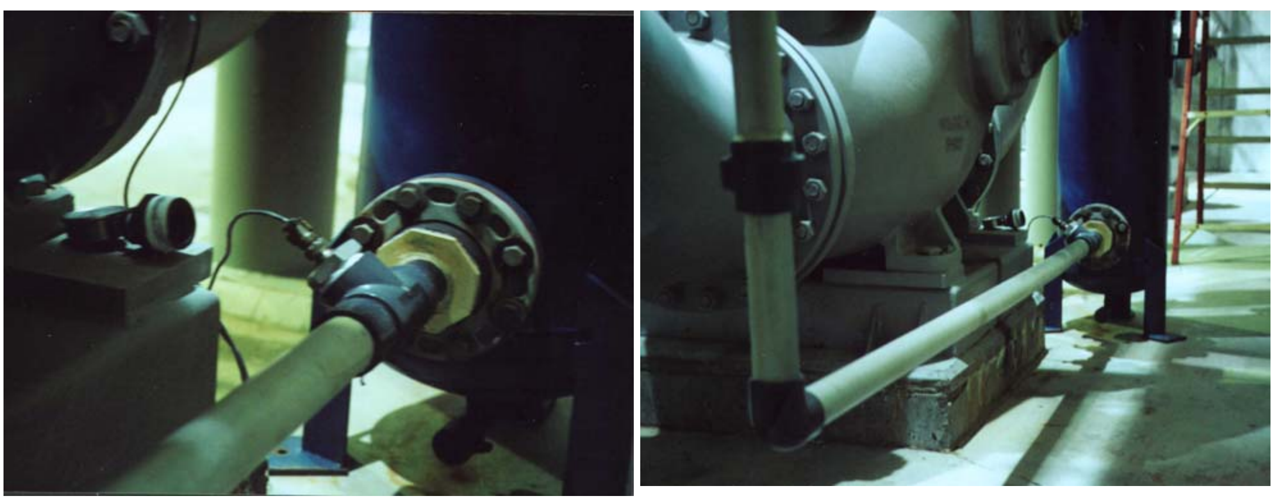

Figure 2. BIoGEORGE ™ Probe Installed in Cooling System at Cove Fort

Experimental Results and Discussion

Data recorded by the instrument from February to September of 2001 is presented in Figure 3. For the data collection, the probe was polarized to a preset potential of 100 millivolts each morning for approximately one hour. The instrument then recorded the applied current required to achieve that potential. Increases in that value may be related to the fouling condition of the probe.

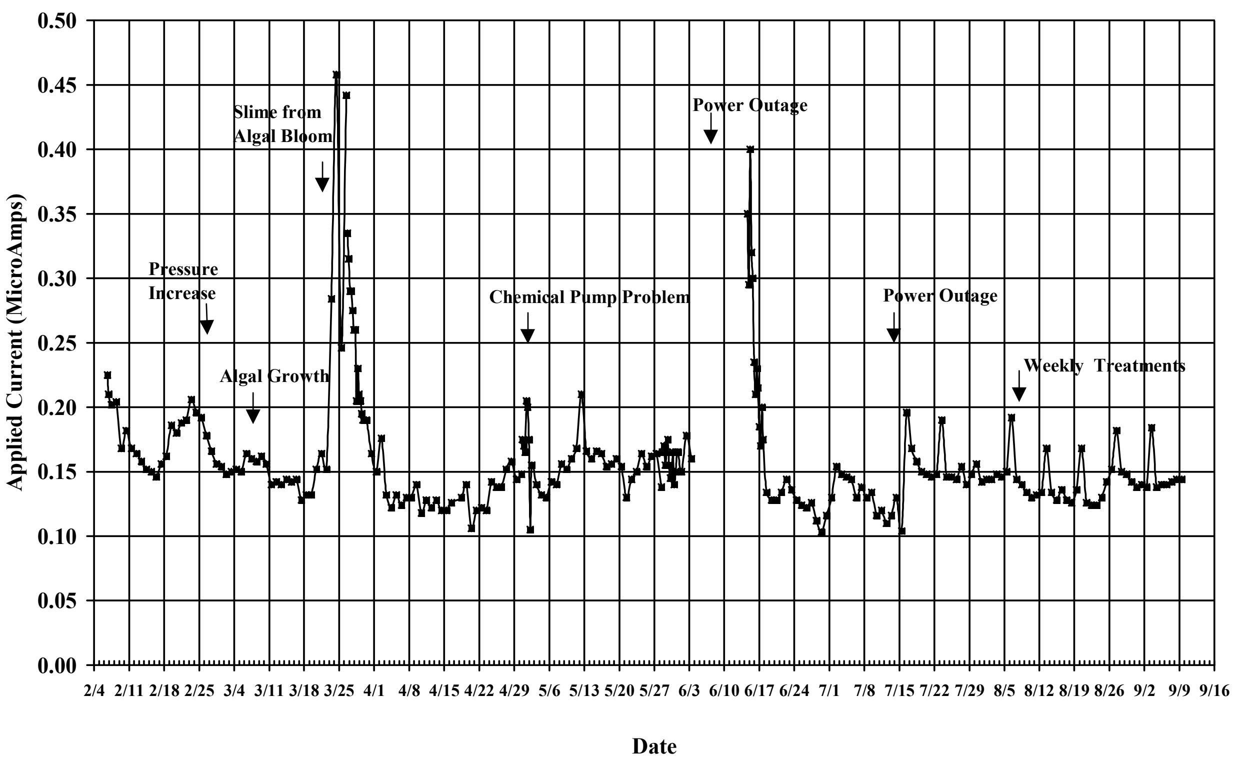

Figure 3. Data Collected by BIoGEORGE™ Biofilm Monitor at Bonnett Geothermal (February-September 2001)

Referring to the figure, the monitor appeared to track with (and in some cases be predictive of) changes that occurred in the plant operation during this period. For example, around February 27, operations personnel noted an increase in back pressure possibly indicating fouling. The BIoGEORGE™ applied current was increasing during the period of time immediately preceding this change. On March 8th algal growth was seen in the cooling tower and by March 22 was producing slime in the system. The monitor showed a very sharp increase in current around this same time. Treatments were applied and the system is shown recovering during the first week of April. The excursions noted in early May are related to problems with the bromine-dispensing system in the tower. A new bromerator was installed on May 2. The gap in data in June was caused by a major power outage experienced by the plant caused by storm damage to the power transmission system. The monitor follows the plant recovery following this event. Another power outage, experienced by the plant on July 15, also produced a significant increase in the current measured by the instrument. The periodic spikes in the applied current, which begin to show up in the data around the July 16, seem to correlate with weekly biocide treatments. It is speculated that these treatments change the conductivity of the water causing these sharp current increases.

In Figure 4, the BIoGEORGE™ monitor data is again shown as a function of time along with an overall condenser thermal resistance that can be calculated from the process data. Two thermal resistances are shown in this figure; one calculated basing the total heat load on the cooling water measurements, and the second based upon the process steam measurements. (The thermal resistance is the inverse of the overall heat transfer coefficient, which is calculated from the heat load, condenser area, and process temperature measurements.) The BIoGEORGE™ data in this figure differs from that in Figure 3, in that the data related to the different operational excursions has been removed. This was done to determine whether the BIoGEORGE™ data would track those trends in fouling that would be indicated by the process data.

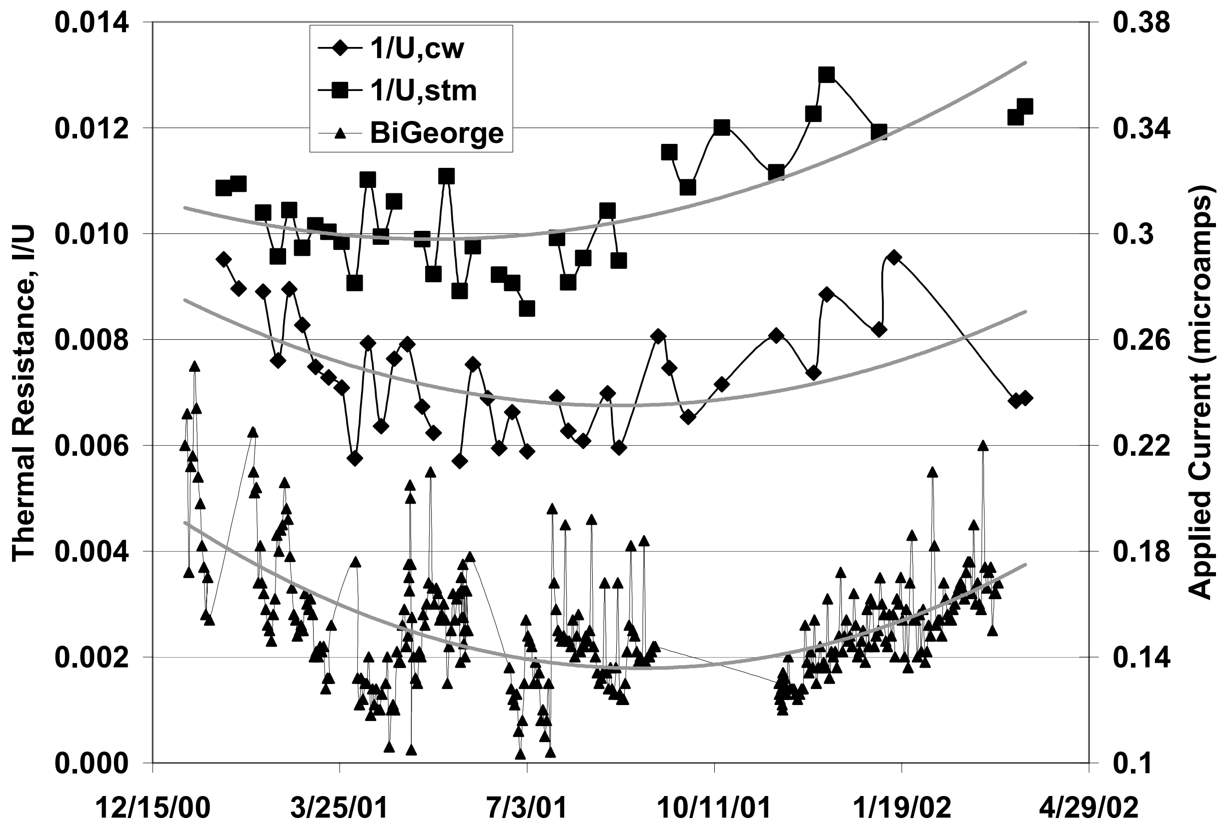

Figure 4. BIoGEORGE ™ Biofilm Monitor Data and Condenser Thermal Resistance Calculated from Process Parameters

Because of uncertainties in process measurements and operating conditions (status of auxiliary systems such as the non-condensable removal system), it is difficult to compare a calculated condenser performance from individual data points to readings from the BIoGEORGE™. However, if the data is examined over time, it is apparent from the results in Figure 4 that the BIoGEORGE™ readings follow a trend similar to that of the total thermal resistance for the condenser. (The trend lines are shown in the figure for each set of data.) All three sets of data indicate that the fouling is at its lowest during the summer months and tends to increase during the cooler periods of the year. This appears to contradict the premise that the bacteria would be most active during the summer months. However, for this particular plant, these trends are reasonable since a more aggressive treatment schedule is used to control microbial growth in the summer.

Conclusions

A preliminary evaluation of a commercial electrochemical monitor, the BIoGEORGE™, for the detection of biofilm formation in geothermal plant cooling systems has been performed. The data collected from the extended deployment of the instrument at Bonnett Geothermal indicates that the system is able to detect, and in some cases predict, the initiation of growth problems. While the instrument is continuing to be evaluated, these initial results suggest that the system shows promise as an indicator of growth in these systems and could be useful in optimizing chemical treatments used at geothermal plants.

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